MINE CLOSURES

BACKFILL CLOSURES

DESCRIPTION

Backfill closures consist of filling mine openings with on-site or imported fill. See Fig. 1. Normally done with heavy equipment; however, can be done by hand for remote and shallow sites.

For adit backfills, an access-way can be provided where there is a need to re-enter the mine for archeology, geology, or NPS administrative purposes.

Advantages: Backfilled sites can be restored, and do not attract vandals or casual visitors. Less monitoring required.

Disadvantages: Wildlife habitat and historic resources in mine are permanently lost. Backfilled shafts may subside, and site should never be used for buildings. Any access through a backfill compromises the advantages.

Cost: $100 to $5,000 per project.

MATERIALS

Backfill: Well-graded rock to minimize voids, durable, impermeable, and insoluble in water. Free of debris or trash and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.

Riprap: Minimum (2 ft*) diameter, hard, durable, and well-graded to minimize voids.

Drainpipe: Noncorrosive, sized for potential flow.

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.*

Grated access door (optional): See separate guideline.

CONSTRUCTION

Clean-Up

Prior to backfilling, remove all wood, garbage, cribbing, or other debris from the mine opening as safe conditions permit.

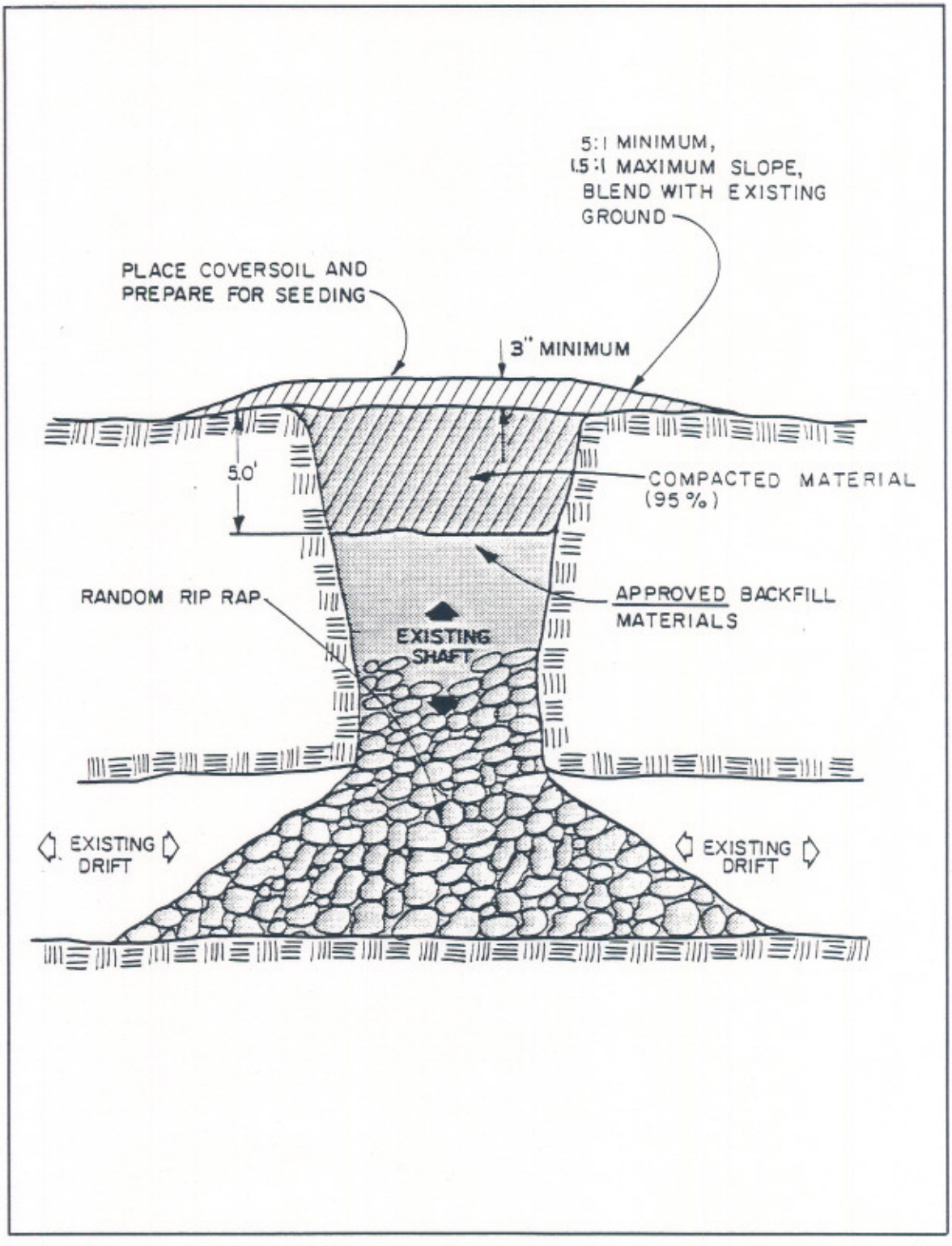

Figure 2. Backfill Closures - Shafts

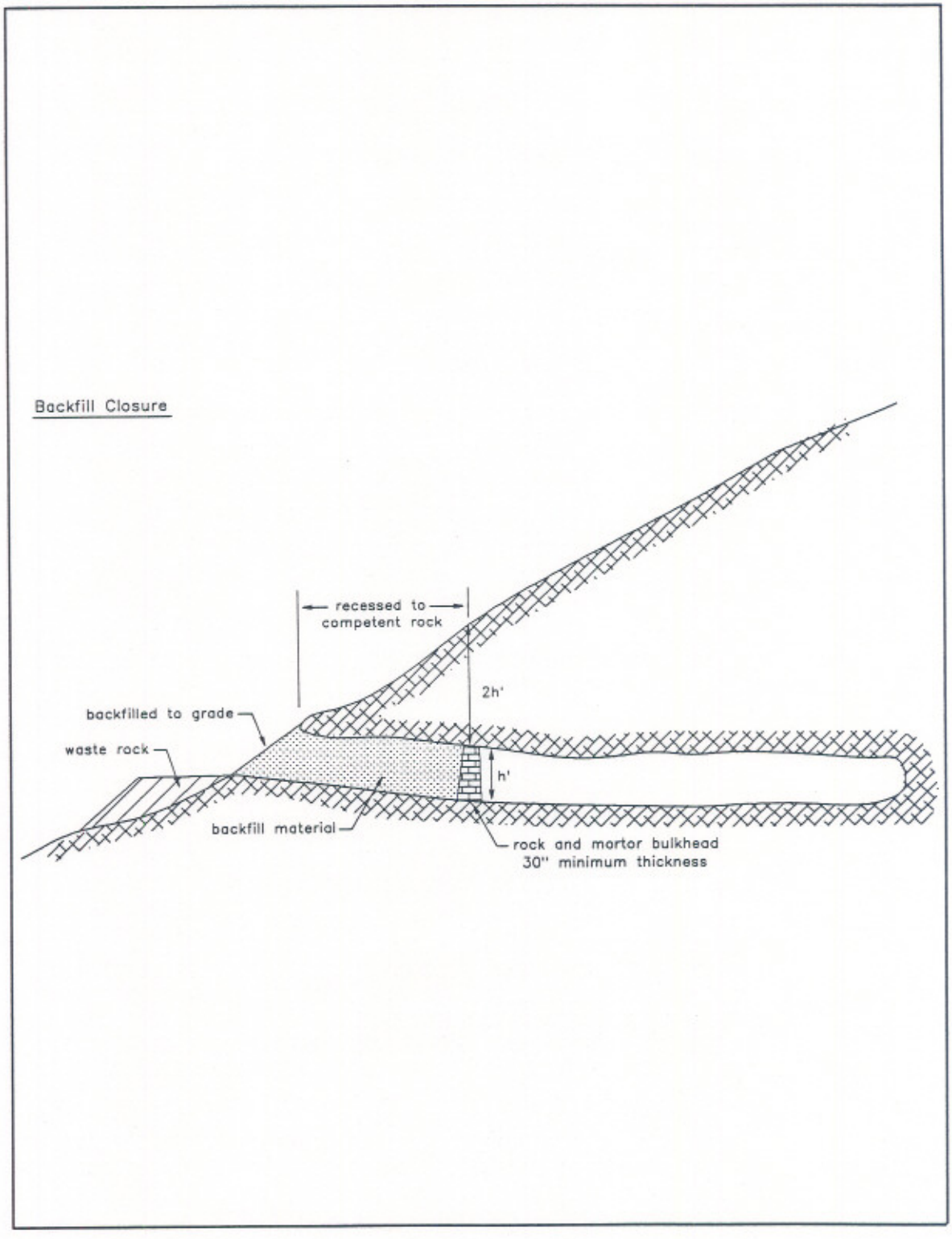

Figure 3. Backfill Closures - Adits

Shafts, Stopes, and Subsidence

Backfill the opening with graded riprap and rock in the following steps (refer to Fig. 2):

* Place a minimum (12 ft*) height of riprap in the bottom of the opening or extending above any intersecting crosscuts.

  ** In deep or water filled openings, place riprap until visible from the edge of the opening.

* Fill remainder of opening with graded rock from on-site or comparable surrounding rock.

* Place rock fill in specified maximum (2 ft*) lifts and minimum thichkness (5 ft*), and compact whenever possible with compactors or available heavy equipment.

* Mound final surface a minimum (3 ft*) height and (2%*) grade above original ground level to allow for settlement.

Adits

If required, install access-way and drainpipe as follows.

* Clear floor of loose rock and debris to create a level bedding surface for culvert/drainpipe.

* Any fill placed to level the floor should not contain rock larger than a maximum (4 in.) diameter, and should be compacted.

* When water discharges from the adit, size a drainpipe for the flow, and perforate (1/2 in. diam holes, spaced 3 in. apart*) on inside end of drainpipe on bottom side.

* Place culvert/drainpipe, and extend both inside and outside ends minimum (5 ft*) distance beyond backfill.

* Prior to backfilling, cover culvert/drainpipe with a minimum (6 in.*) thickness of compacted fill.

Backfill the opening 1) a minimum (15 ft*) distance beyond the weathered zone, 2) a minimum 15 ft* distance beyond any fractures induced by the mine opening, or 3) a minimum brow thichness of twice the mine opening height whichever is greater. See Fig. 3. Measure length of backfill along top of fill. Take care not to damage culvert and drainpipe. Additional requirements:

* No spaces between top of fill and roof of the adit that exceed a minimum (3 in.*) height.

* No space between top of fill and roof at the entrance to the adit.

* Entire length of backfill must have rocks individually weighing more than a specified minimum (150 lb*) to reduce erosion and discourage people from digging through backfill.

Install Monument See separate guideline.

REFERENCE: This section paraphrased from CMLRD, 1989, p. 21.

BLAST CLOSURES

DESCRIPTION

Blast closures consist of filling or collapsing mine openings through the use of explosives. See Fig. 4. This closure method permanently prevents access to the mine.

Advantages: The site can be restored. Blasting can be used on openings that are too unstable and unsafe for other methods. For remote sites that do not require drilling, explosives can be backpacked.

Disadvantages: Requires experts and almost always involves some amount of trial and error. Wildlife habitat and historic resources in mine are permanently lost. Backfilled shafts may subside, and site should never be used for buildings.

Cost: $500 to $4,000 per project.

BLASTING PLAN

Blasting requires an expert to design and supervise the operation. The expert must have relevant experience, a Federal license, and usually a State license for both the storage and use of explosives. Blasting plans involve the following:

* Type of explosives and blasting agents.

* Blast hole pattern, powder factor, and charge design.

* Detonation method and timing.

* Direction of fly rock, maximum allowable wind velocity, date and time of blast.

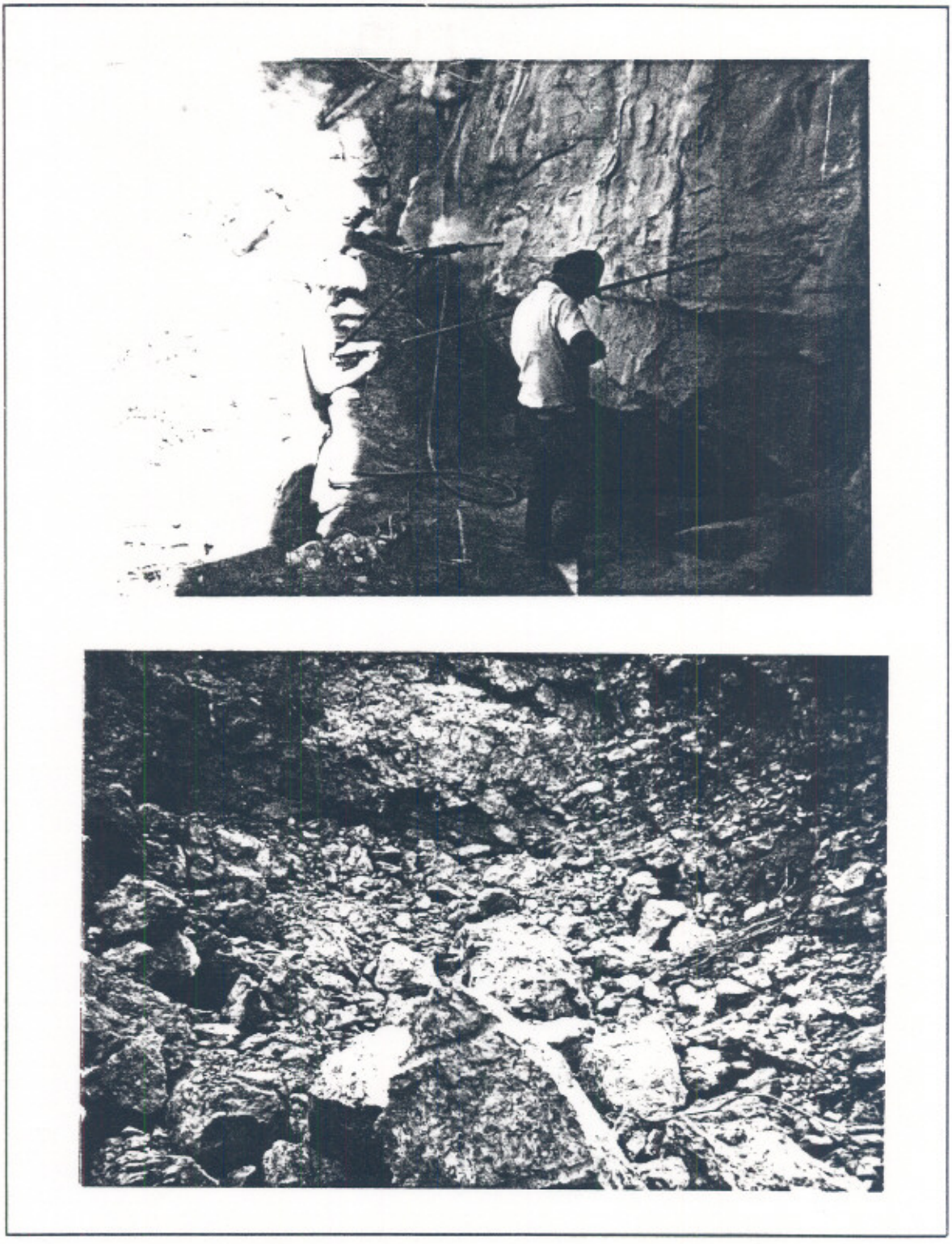

Figure 4. Blast Closures

* Provisions for employee and public safety.

* Compliance with local regulations and notification of local law enforcement.

REFERENCE FOR STATE AND LOCAL REGULATIONS

* Applicable Federal regulations:

** 30 CFR Parts 1 to 199

** 30 CFR Parts 700 to End

MATERIALS

Drainpipe: Noncorrosive, sized for potential flow.

CONSTRUCTION

Collapse mine opening by controlled blasting for a minimum (15 ft*) depth beyond whichever is greater 1) the surface, 2) weathered zone, or 3) fractures induced by the mine opening. See Fig. 4. If conditions permit, drill blast holes and blast from inside the mine opening. Additional requirements include the following:

* Place a backstop at the specified minimum depth to force blasted rock to fill the mine opening.

* Entire length of blast fill must have rocks individually weighing more than a minimum (150 lb*) to reduce erosion and discourage people from digging through fill.

* No spaces that exceed a minimum (3 in.*) height .

* No spaces at the entrance.

* For adits that discharges water, place on the floor a drainpipe sized for the flow.

** Perforate inside end of drainpipe on under side (1/2 in. diam holes, spaced 3 in. apart*).

** Extend both ends of drainpipe a minimum (5 ft*) distance beyond blast area.

** Prior to blasting, cover drainpipe with a minimum (6 in.*) thickness of compacted fill.

Install Monument See separate guideline.

REFERENCE: This section paraphrased from CMLRD, 1989, p. 23; CMLRD, 1990, p. 4.

CONCRETE CAP SHAFT CLOSURES

DESCRIPTION

Concrete caps or slabs placed over shaft openings are an intermediate closure method intended for use where the need may arise to re-enter the mine in future. See Fig. 5. The caps can be removed although not without considerable effort. In addition, culverts can be placed through the caps, if access is required for NPS administrative purposes.

Caps are constructed from a choice of slab either precast or cast-in-place, and a choice of slab support either steel beams or hollow core footings. If a park has numerous open shafts, precast concrete panels are an efficient and economical method of closure. Steel beams provide slab support where the shaft rock is competent, and hollow core footings where the rock is incompetent.

Construction involves clearing and grubbing, excavation of footings, installation of forms and reinforcing steel or steel beams, concrete work or placement of precast panels, installation of access-way (optional), and backfilling.

Advantages: Relatively inexpensive if there is road access to the site. Adaptable to a variety of site conditions. Moderately vandal proof.

Disadvantages: In time, cap may subside into mine opening if not constructed properly. Cap may deteriorate in 30 to 50 years. Only provides for public safety; does not restore natural environment or provide access for wildlife.

Cost: $3,000 to $5,000 per project.

MATERIALS

For Cast-In-Place Caps

Concrete and reinforcing steel: Refer to NPS specifications.

Forms: Wood or stay-in-place corrugated metal.

Drainpipe: Noncorrosive, 2 in. diam*.

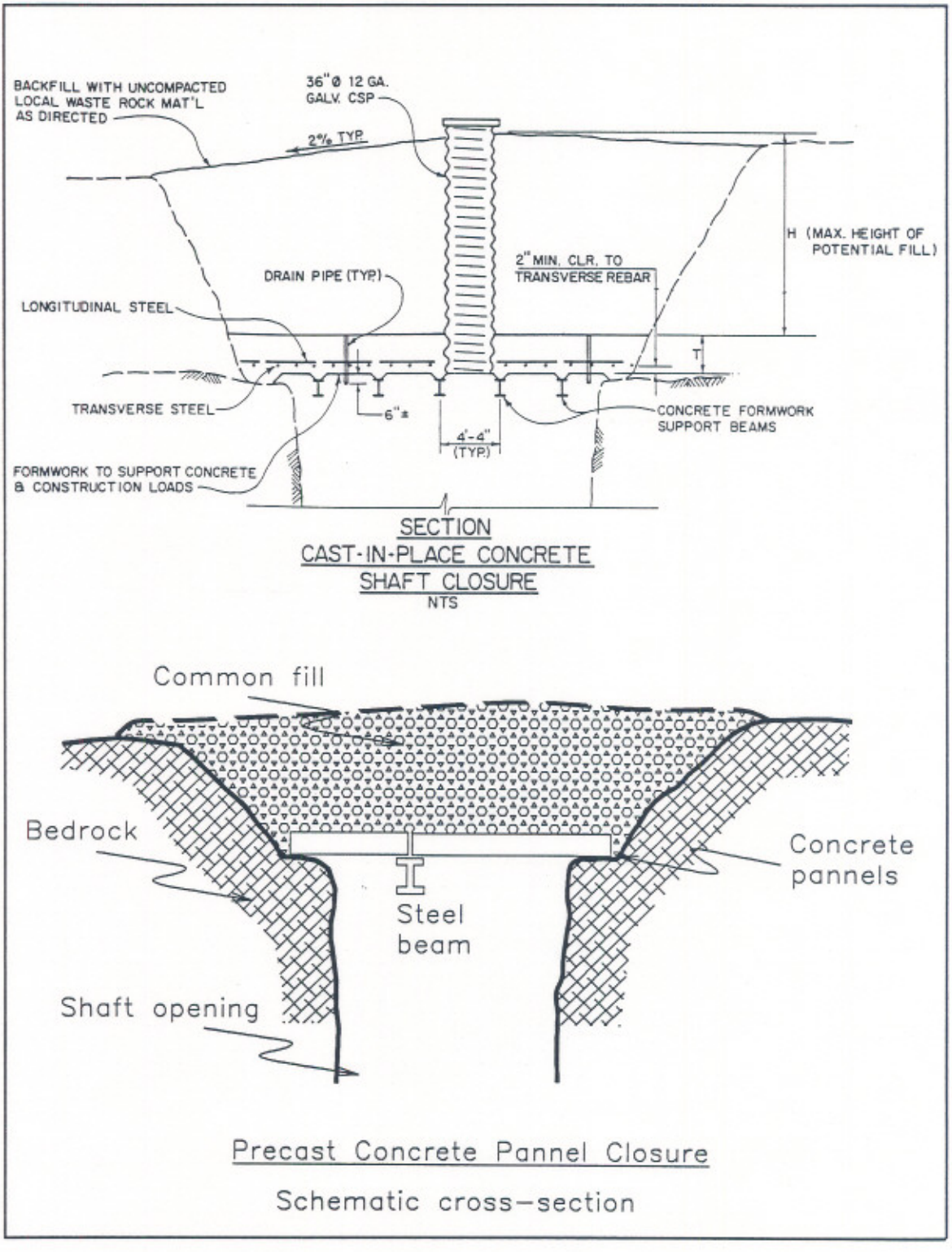

Figure 5. Concrete Cap Shaft Closures
(CMLRD, 1990)

For Precast Panels

Precast concrete panels: Supplied and delivered by a manufacturer to storage areas near the project site. Refer to NPS specifications. One panel may have an optional opening for installing an access way.

Steel beams, tie bars, and plates: Specified by a qualified structural engineer. Specify minimum (6 in.*) width of beams to provide an adequate bearing surface for panels.

Sacrete: Or equivalent.

For Both Cap Types

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.*

Grated access door (optional): See separate guideline.

Backfill: Unclassified rock and soil free of debris or trash, and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.

CONSTRUCTION

Clearing and Grubbing

Clear and grub vegetation, debris, loose rocks, and other items that interfere with construction.

For Competent Rock - Excavation And Beam Installation

On occasion, excavation may reveal conditions that necessitate plan revisions. Contractors should be made responsible for site inspections to insure that their bids adequately reflect excavation conditions.

Competent rock is defined as rock which 1) cannot be readily removed by a medium sized excavator (weighing in the 45,000 to 55,000 lb range*), and 2) does not have adverse jointing which may slip and cause failure of the closure.

Excavation:

* Locate beam footings in competent rock.

* Excavate soils, loose and weathered rock in general compliance with construction drawings.

* Beams and slab overlap competent rock by a minimum (1 ft*) length.

* Overlap must be equal on opposites sides of closure.

* Each slab side must have more than two thirds of its length resting on planar rock or concrete surface with no gaps greater than a specified minimum (1 ft long and/or 6 in. deep*).

* Fill low foundation areas (not more than a minimum 1.5 ft* depth) with compacted and confined waste rock or concrete.

Beam Installation:

* Prior to installation, coat steel beams with bituminous tar or epoxy resin for corrosion protection.

* For precast panels, set steel beams perpendicular to the long dimension of panels, and set top of beams in the plane of panel footings.

* Place steel beams on a concrete leveling course with minimum specified thickness (3 in.*).

* Encase steel beams totally in concrete for the entire length of footings, except for top. Specify a minimum (3 in.*) thickness of concrete as measured from outermost extremities of beam.

For Incompetent Rock - Hollow Core Footing

Hollow core footings are required where rock in shaft opening is inadequate to support beams and concrete slab. Definition of competent rock given under preceding subsection.

Excavation:

* Excavate soils, loose and weathered rock in a truncated cone shape leaving a minimum (1 ft*) ledge width in unweathered rock.

* For precast panels, outside ledge dimensions must match panel dimensions.

Construct hollow core concrete form as follows:

* Minimum (4 ft*) height.

* Specify height such that top of form is a minimum (2 ft*) distance from side walls of shaft.

* Install cross supports (4 ea 2X4's on 4 ft spacing*) in forms exceeding a maximum (8 ft*) height.

* Install hangars and reinforcing steel as specified by a qualified structural engineer.

* For precast panels, install steel tie plates with anchors.

* If form is to be removed, treat concrete contact surfaces with a bond-breaking coating. Coating must also prevent absorption of water where plywood forms are used.

* Construct form on surface and lower into shaft opening directly from overhead.

* Place rocks around toe of form to stabilize it from movement. Rocks should not fill more than a maximum (2 ft*) height, and should not disturb reinforcing steel.

Cast-In-Place Cap Forms

Construct forms for the cast-in-place cap using corrugated metal stay-in-place forms, and steel or wood support beams.

* Forms should be mortar tight and sufficiently rigid to prevent distortion from pressure of the concrete, vibration, and other incidental construction loads.

* Lay reinforcing steel into form using plastic chairs or equivalent to support steel the proper distances.

* Reinforcing steel must be tied together and not welded.

* Install pipe (2 in. diam on 4 ft centers*) to drain water through the cap.

If an access-way is required, install culvert prior to pouring concrete, as follows:

* Form an opening the same size as culvert.

* Secure culvert to form opening and to the surface with guy wires.

* Install diagonal reinforcing steel around opening.

* Bottom culvert rim must rest on cap form or horizontal beams without obstructing culvert opening.

* Extend culvert a minimum (1 ft*) height above the backfill surface.

Concrete Placement

Concrete may be mixed at site or delivered by a commercial service.

* Inspect and approve forms prior to pouring concrete.

For the hollow core footing:

* Place concrete around outside and to top of the form.
* Pour in maximum (15 - 20 in.*) lifts.
* Systematically consolidated concrete using mechanical vibrators, and insure that the junction between layers is adequately vibrated.

For the cast-in-place cap:

* Control pouring rate to prevent deflection of the forms.
* Spade concrete by hand around reinforcing steel, and systematically consolidated using mechanical vibrators.
* Insert a pipe flange in concrete for monument pipe.

Concrete samples must be taken and tested in compliance with NPS specifications.

Precast Panel Installation

* Place precast concrete panels on panel end footings, and hollow core footing or steel beams.

  No more than a maximum (1 in.*) space between panels.

  Panel edges within a minimum (2 in.*) distance of beam center line.

  For adjacent panels not resting on a beam, minimum (6^{o} *) deviation from a planar surface, and maximum (3 in.*) vertical gap.

* Panels must rest uniformly on footings and beams (no discernable rocking*). Under some circumstances, minor inadequate leveling can be corrected by shimming or additional footing concrete.

* If panels are placed more than a specified angle (15^{o}*) from horizontal, key in and anchor panels to competent

rock. Specify anchors (#8 rebar or rock bolts, 18 in. deep, spaced on 24 in. centers*).

* Remove lifting hooks from panels.

* Tack weld beam tie bars to panels.

If an access-way is required, secure culvert to opening in panel, and extend culvert a minimum (1 ft*) distance above backfill surface.

Install Monument See separate guideline.

Backfill and Drainage Berms

If cap is more than a maximum (8 ft*) depth below ground surface, backfill cap completely. Cast-in-place caps must reach a minimum (3,000 psi*) compressive strength prior to loading or backfilling.

Where a vertical culvert is not required:

* Backfill excavation with uncompacted rock to a maximum (1.5h:1v*) gradient. Toe of backfill should overlap cap sides by a minimum (2.5 ft*) distance, but should not cover optional grate, if installed.

* With uncompacted rock, construct drainage control berms to direct surface runoff away from opening. Specify appropriate berm design for local runoff conditions.

Where a vertical culvert is installed:

* Place backfill in maximum (2 ft*) lifts, compact with mechanical compactors or available heavy equipment.

* Mound final surface a minimum (1 ft*) height and grade (2%*) above original ground level to provide drainage away from closure.

Weld a grated and locked access door to the top of the culvert or opening in cap, as appropriate. Weld must be continuous around the grate.

REFERENCES: This section paraphrased from CMLRD, 1989, p. 25; CMLRD, 1990, p.5.

MONOLITHIC PLUG SHAFT CLOSURES

DESCRIPTION

Monolithic plugs simply consist of pouring a specified (4 ft*) layer of concrete over mine shafts that have collapsed at the collar and have no apparent opening. May also be used for small subsidence features. The construction includes clearing and grubbing, excavation, placing riprap, and pouring concrete.

Advantages: Relatively inexpensive if there is road access to the site. Adaptable to site conditions. Moderately vandal proof.

Disadvantages: In time, cap may subside into mine opening if not constructed properly. Concrete may deteriorate in 30 to 50 years.

Cost: $1,000 to $3,000 per project.

MATERIALS

Concrete: Refer to NPS specifications.

Riprap: Hard and durable with a minimum (2 ft*) diameter.

Backfill: Unclassified rock and soil free of debris or trash and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.

CONSTRUCTION

Clearing and Grubbing

Clear and grub vegetation, debris, loose rocks, and other items that interfere with construction.

Excavation

In most cases, no excavation is necessary because the shaft has collapsed to dimensions larger than the original cross section dimensions. If current dimensions are smaller than original dimensions, excavate opening to a cone shape so that plug dimensions exceed original dimensions by a minimum (2 ft.*) width on all sides.

Riprap Installation

Place a minimum (2 ft*) thickness of riprap in the bottom of the shaft depression. Finish riprap with a generally flat top such that no rock extends more that a minimum (2 ft*) height above the average level.

Concrete Pouring

Concrete may be mixed at site or delivered by a commercial service.

* Pour concrete over riprap for a minimum (4 ft*) thickness that includes the riprap thickness.

* Compact concrete thoroughly by a mechanical vibrator.

* Vibrating must be supplemented with hand spading to work concrete into riprap.

Concrete samples should be taken and tested in compliance with NPS specifications.

Install Monument See separate guideline.

Backfill

After concrete attains minimum (3,000 psi*) compressive strength, backfill plug. Mound backfill a minimum (2 ft*) height and (2%*) grade above the surrounding area to insure drainage away from the closure.

REFERENCES: This section paraphrased from CMLRD, 1989, p. 36; CMLRD, 1990, p. 5.

STEEL GRATE CLOSURES

DESCRIPTION

A steel mesh of expanded sheet metal, heavy steel rods, or angle iron is supported by a rigid steel frame, and cemented or bolted over an opening. See Fig. 6. This closure method is intended for use where there is a need to provide access for wildlife (bats, ring tail cats, spotted owls) or a need to frequently re-enter the mine (archeology, geology, NPS administrative purposes). Construction involves clearing and grubbing, excavation of loose material, trimming opening, fabricating, and installing grate.

Advantages: Openings are closed for public safety, yet retain access. Effective at preventing accidental or intentional entry. Can be recessed to minimize visual intrusions. Should last indefinitely in arid climates. Allows natural ventilation. Smaller grates can be transported by helicopter or grates can be assembled on-site.

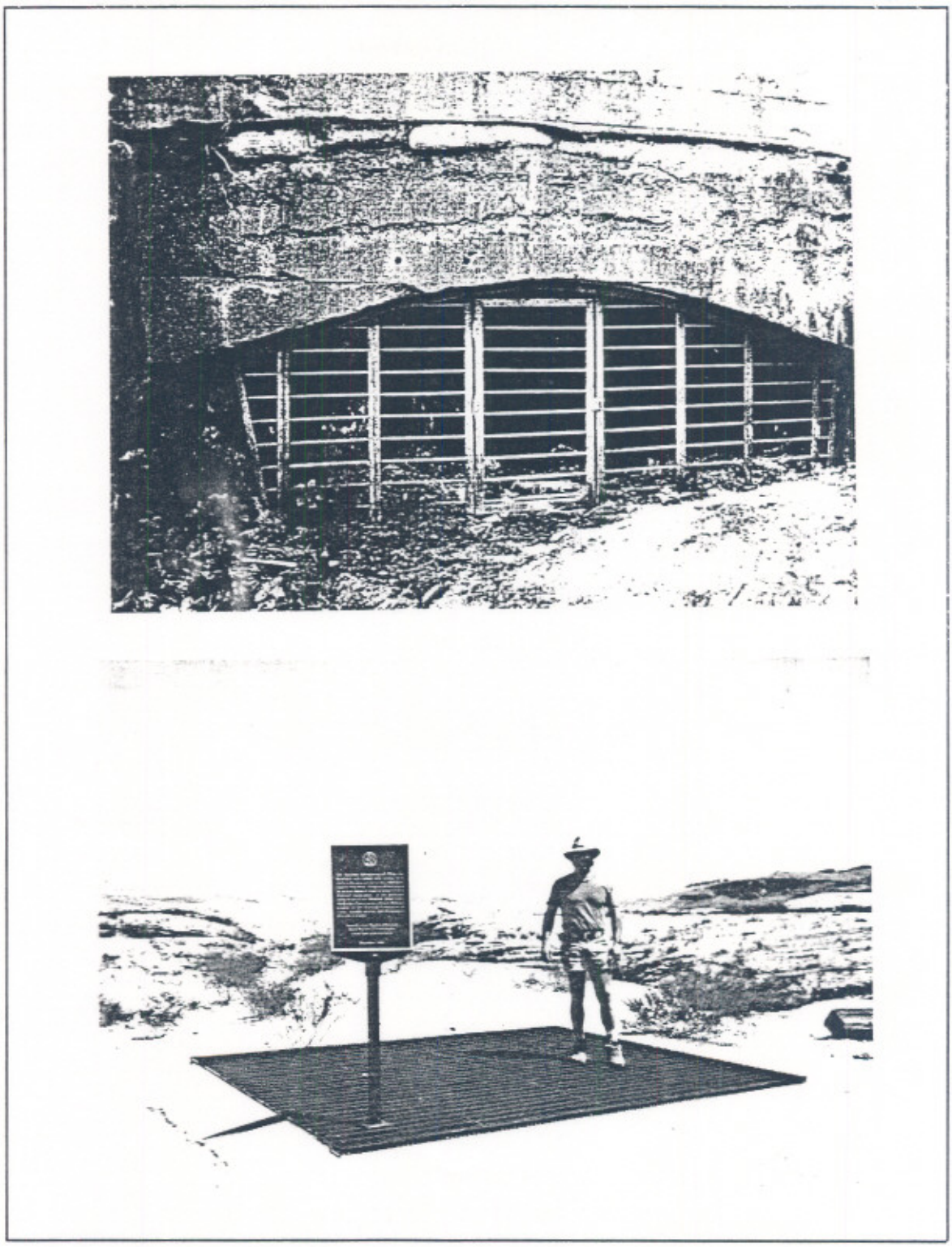

Figure 6. Steel Grate Closures

Disadvantages: Each grate must be custom designed. Installation is difficult away from road access. Rock foundation may weather and deteriorate with time. Grates are often defeated by persistent vandals. Require regular monitoring and maintenance. Can be visually intrusive, but massive appearance may deter unwanted entry.

Cost: $1,000 to $7,000 per project.

MATERIALS

Steel grating: Openings (1-1/4 in. by 1 in.*), bearing bars (15/16 in.* centers), and cross bars (2 in.* centers). Equivalent commercial grating is also available.

For adit bat gates, openings must be oriented horizontally with minimum (6 in. by 24 in.*) dimensions. Grate must be fabricated from heavy steel rods or angle iron. Modify grate design for the requirements of particular species.

Structural steel specified by structural engineer.

Footing Concrete: Refer to NPS specifications.

Anchors: Either 1) expansion rock bolts with minimum (2000 lb*) pullout for competent rock, or 2) reinforcing steel of minimum (No. 6 rebar*) size and (18 in.*) length as required by rock conditions.

Anchor Grout: Nonshrink mortar or epoxy resin capsules.

CONSTRUCTION

Clearing and Grubbing

Clear and grub vegetation, debris, loose rocks, and other items that interfere with construction.

Fabrication

On-site, cut commercial grating or weld together custom grating to fit irregularities of the opening.

* Weld grating to angle iron framework, every other bearing bar and all cross bars on both sides.

* Weld all edges of grate to each other.

* Chip, wire brush, and completely remove slag from welds.

* After cleaning, paint welds and steel with a zinc-rich protective coating.

* Welds must meet applicable standards of the American Welding Society.

Adit Excavation and Grate Installation

Specify a stable location not more than a given (10 ft*) distance from opening. Trim opening to provide a uniform contact for the grate frame. If stable roof and sides are not found, select another closure method.

If the floor is unstable, excavate and construct a floor footing as follows:

* Minimum (8 in*) width extending across entire adit.

* Depth to competent rock or a minimum (3 ft*) distance below grade line.

* Drive (No. 6 rebar*) anchors on specified (18 in.*) centers and minimum (36 in.*) depth. Extend anchors a minimum (8 in.*) distance above footing.

* Install reinforcing steel, pour and vibrate concrete.

If the floor is competent rock, set anchors as follows:

* Specify minimum anchor depth (8 in. for rock bolts, 18 in. for grouted reinforcing steel*), and minimum (8 in.*) distance anchor extends into opening.

* Drill holes on specified (18 in.*) centers and slightly greater in depth than anchors.

* Insert non-shrink grout and anchors.

Weld grating frame to anchors. Weld a (2 in. by 3/8 in.*) strap between anchors and around the perimeter of the grate at a specified maximum (4 in.*) distance from the edges of the opening. Welds should meet specifications given in Fabrication subsection.

Shaft Excavation and Grate Installation

Grate dimensions must extend a specified (1 ft in competent rock, 3 ft in incompetent rock*) distance beyond shaft opening.

Clear loose rocks and trim opening to provide a uniform contact with frame.

* Fill all voids between frame and opening larger than a maximum (1 in.*) width with mortar, rock wall, pieces of welded grating, or angle iron.

* Where gaps between the frame and bedrock exceed a maximum (6 in.*) height, fill gap with a mortared and durable rock wall of minimum (6 in.*) width.

In competent rock, set anchors as described above for adits.

If rock is incompetent, construct spread footings for frames as follows:

* Minimum (8 in.*) column diameter and base (24 by 24 in. for spans up to 30 ft, 30 by 30 in. for spans greater than 30 ft*).

* Depth to competent rock or minimum (3 ft*) below grade line.

* Maximum (10 ft*) spacing or less as required by irregular outline.

* Build concrete forms, install reinforcing steel as specified by structural engineer - minimum of four vertical rebar. Extend two of four vertical rebar above footing for welding to grate.

* Pour and vibrate concrete.

If shaft opening exceeds a maximum (3.5 ft*) span, install supporting steel beams as specified by a qualified structural engineer.

* Extend beams a minimum (1 ft*) distance beyond both sides of grating.

* Excavate footings for beams a minimum (3 in.*) beyond outer extremities of beams.

* Embed and cover beams in mortar for the entire length of footings except for beam top where grating is placed.

Weld grating frame to beams and anchors.

* First, remove any paint from weld areas prior to welding.

* Weld every other bearing bar of grating to support beams.

* After welding, paint steel with a zinc-rich protective coating.

* Welds should meet specifications given in Fabrication subsection.

Install Access

If ready access is required, cut and weld a doorway or hatch into grate (bottom center for adits and center for shafts.) See separate guideline.

Drainage Berms

With uncompacted rock, construct drainage control berms to direct surface water runoff away from shaft opening. Specify appropriate berm design for local runoff conditions.

Install Monument See separate guideline.

REFERENCES: This section paraphrased from CMLRD, 1989, p. 38 & 53; CMLRD, 1990, p. 7.

CABLE NET CLOSURES

DESCRIPTION

Cable nets are made of stainless steel cable with all intersections locked to form a 6 in. mesh or as required for wildlife access. See Fig. 7. The nets are anchored in or over a mine opening with rock bolts.

Advantages: Effective in preventing accidental and intentional entry. Allow small wildlife to pass including small bat species. Can be recessed to minimize visual intrusion. Flexible in being adapted to odd shaped openings including those with historic resources. Resistant to most vandals.

Disadvantages: Barrier to large bat species, although the net can fabricated with a larger mesh. Site is not restored. May create a challenge to visitor because one can see beyond barrier and it appears vulnerable. Nets can be cut with cable cutters but not the more commonly available bolt cutters.

Cost: $300 to $3,000 per project.

MATERIALS

Cable: Steel minimum 1/4 in.* diameter, crimp connectors.

Anchors: Either 1) expansion rock bolts with minimum (2000 lb*) pullout for competent rock, or 2) reinforcing steel of minimum (No. 6 rebar*) size and (18 in.*) length as required by rock conditions.

Grout: Nonshrink mortar or epoxy resin capsules.

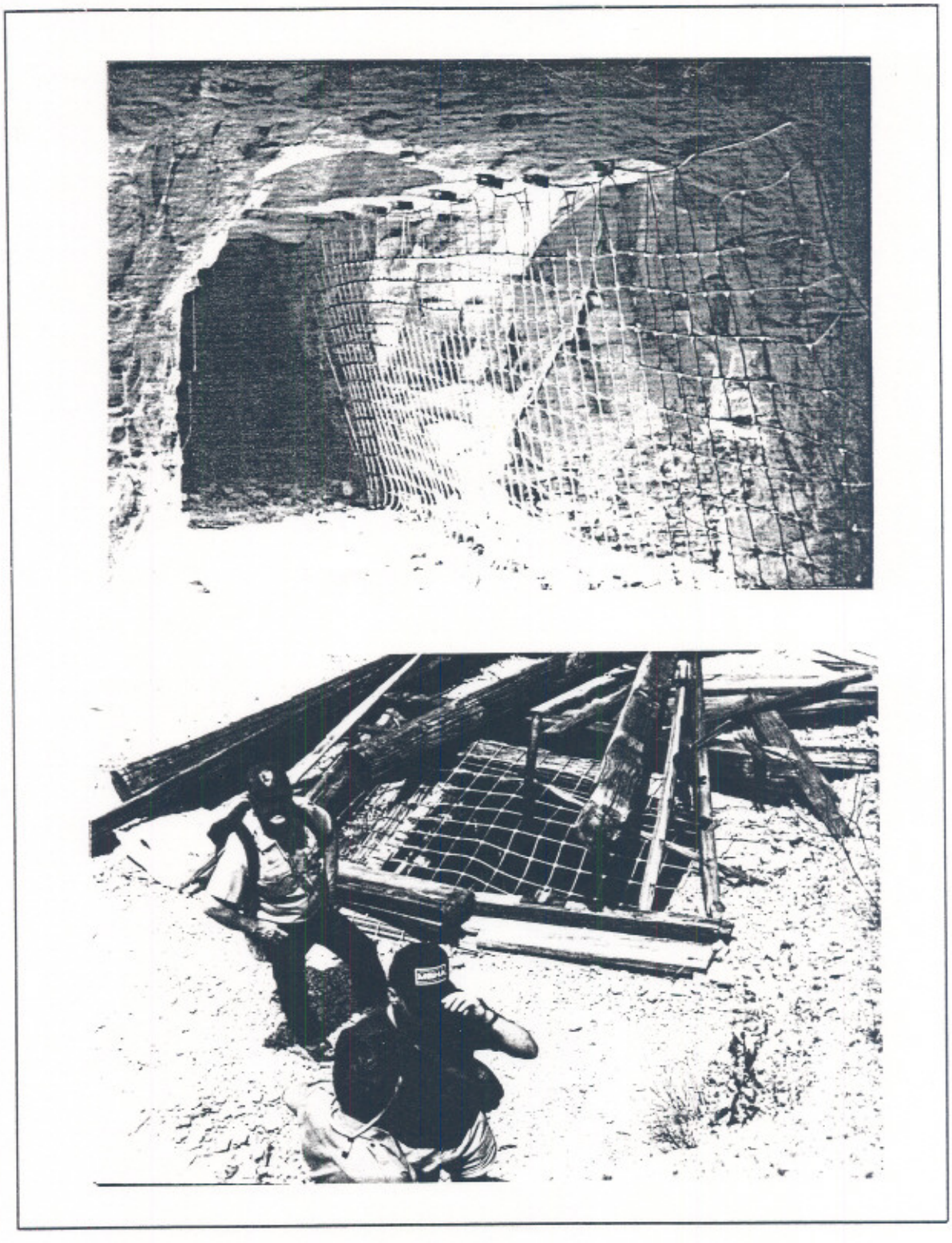

Figure 7. Cable Net Closures

TOOL LIST

Rock drill, drill rods, bits, and air compressor.
Cable sleeve crimper.
Cable cutter.
Sledge hammer.
Shovel.
Come-along.

CONSTRUCTION

Fabrication

Construct a jig to weave steel cables into a net configuration, typically 7.5 ft square. Stretch cable tightly and join intersections with hydraulically crimped two part steel sleeves. Crimped sleeves are preferable to wire rope clips because sleeves are more difficult to vandalize. If clips are used, the bolt heads must be stripped to prevent removal.

In the field, cut and join nets (crimped sleeves) to custom fit particular opening.

* For shafts, locate net over opening, and extend net a minimum distance (2 ft*) beyond opening.

* For adits, locate net over opening as for shafts, or locate net inside opening not more than a maximum (10 ft*) distance from surface. Inside closure is applicable only where rock is competent. Inside closure must have no gaps between adit walls and net greater than a maximum (4 in.*) width.

Holes may be cut in the net, and then closed with cable sections and crimped sleeves in order to fit net around projections or historic objects.

Anchors

For overlapped nets, place anchors a minimum of 4 to 5 ft back from net edges to provide room to tighten cables.

In competent rock, set anchors as follows:

* Specify minimum anchor depth (8 in. for rock bolts, 18 in. for grouted reinforcing steel*), and minimum (8 in.*) distance anchor extends into opening.

* Drill holes on specified (18 in.*) centers and slightly greater in depth than anchors.

* Insert non-shrink grout and anchors.

For openings with incompetent rock, set anchors as follows:

* Specify minimum anchor depth (3.5 ft*), and minimum (8 in.*) distance anchor extends above surface.

* Drive anchors into ground with sledge hammer. Mechanical methods are also available.

Installation

Weave boundary cables through net and perimeter rings on anchors, and connect ends. Tighten cables with come-along. If required, attach padlock shield.

Where possible, cover perimeter of nets with rock and dirt to obscure anchors and connectors.

Install Monument See separate guideline.

REFERENCE: This section paraphrased from Essington, 1988.

POLYURETHANE FOAM CLOSURES

DESCRIPTION

Polyurethane foam (PUF) closures consist of installing a bottom form, spraying PUF over the form to a minimum thickness, and then backfilling with common fill. See Fig. 8. Ventilation/drainage pipes, access-way, and locking grates may be installed, as required.

This closure method can be permanent or access-way can be installed where there is a need to re-enter.

Advantages: Materials are easily transported to remote sites. Forms require little structural strength. Site can be restored. Backfilled openings do not attract vandals or casual visitors. Less monitoring required.

Disadvantages: Wildlife habitat and historic resources in mine are permanently lost. Backfilled shafts may subside, and site should never be used for buildings.

Cost: $1 500 to $8,000 per project.

MATERIALS

Form and cross supports: Any commonly available building materials capable of sustaining the initial 2 to 4 ft of PUF. Form material must be physically and chemically inert to PUF. Examples of acceptable form materials include any combination of the following:

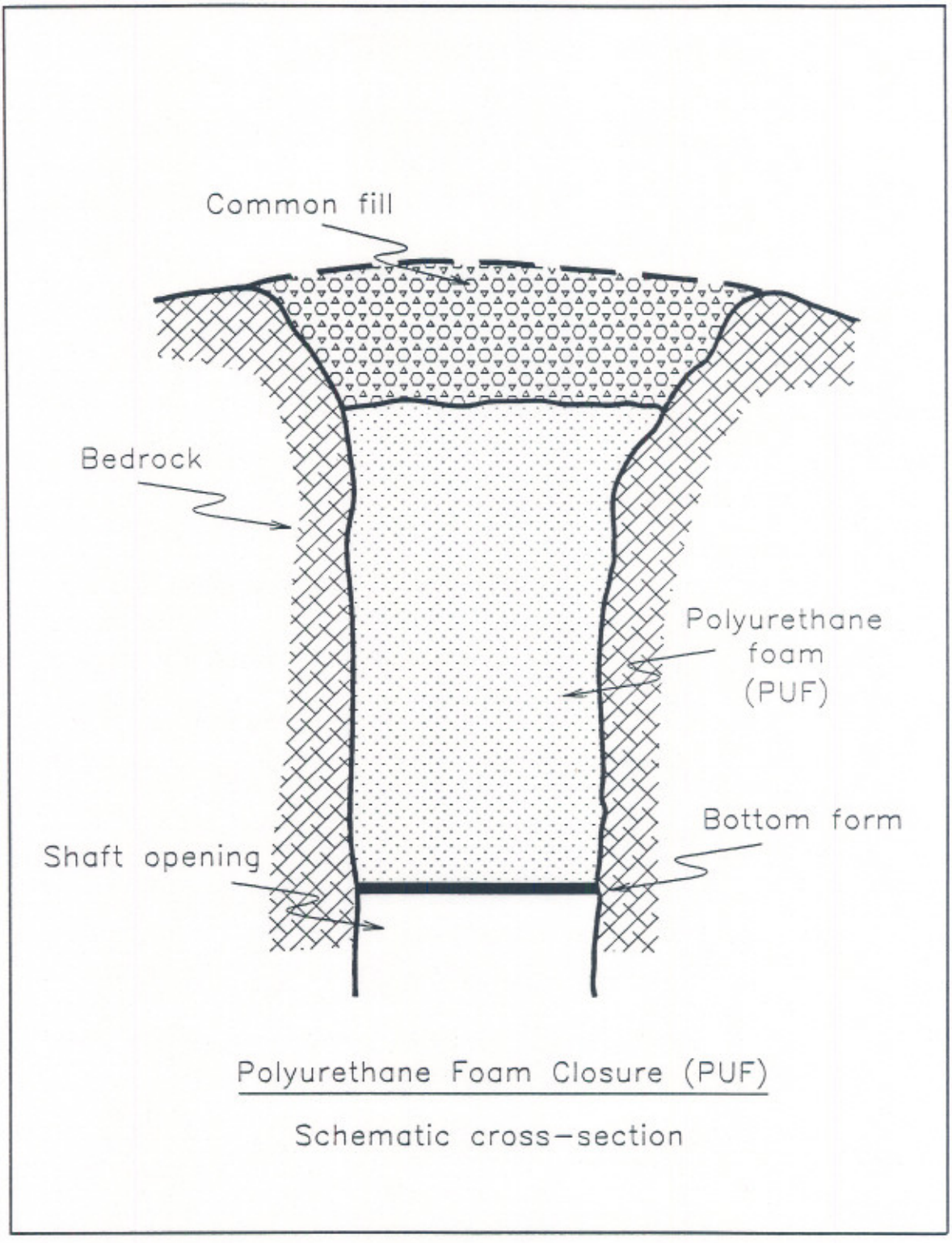

Figure 8. Polyurethane Foam Shaft Closures

Form	Cross Support
Plywood	Rebar
Cardboard	2 X 4's
Panelling	Dowels
Carpeting	Cardboard Tubes

Polyurethane foam (PUF): The Colorado Mined Land Reclamation Division recommends the following minimum standards:

PUF CHARACTERISTIC	STANDARD	REFERENCE .
Density	1.85 lb per cu ft	
Closed cell content	90%	ASTM D-2856
Compressive strength	25 psi	ASTM D-1621
Water absorption	1% by volume	ASTM D-2127
Exothermic reaction rate	Low	
Fire resistance		ASTM D-1692

Estimate the required thickness of PUF from Table VII, as follows:

* Enter the table with the shortest dimension of the mine opening cross section, and the depth from the opening to the bottom form. At the intersection, read the required PUF thickness.

* To get total PUF volume in cubic yards, multiply PUF thickness by mine opening cross section width and length, and then divide by 27 cu ft per cu yd.

* Adjust total for significant irregularities in the sides of the mine opening and any access-way or pipes placed in the PUF.

Proportioning unit: Minimum (125° F*) temperature with heated hose. Hose must maintain or increase PUF temperature from the proportioner to the application gun.

Application gun: Mix PUF components in the proper ratio at a minimum (4 lb per min*) output.

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.*

Grated access door (optional): See separate guideline.

Backfill: Unclassified rock and soil free of debris or trash and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.

TABLE VII
POLYURETHANE FOAM THICHKNESS

Depth to Form (ft)	Shortest Mine Opening Dimension (ft)							
	3	4	5	6	7	8	9	10
5	2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	2.9	3.7	N/A	N/A	N/A	N/A	N/A	N/A
7	3.2	4.2	5.0	N/A	N/A	N/A	N/A	N/A
8	3.4	4.6	5.5	N/A	N/A	N/A	N/A	N/A
9	3.7	5.0	6.0	6.8	N/A	N/A	N/A	N/A
10	4.0	5.4	6.5	7.4	N/A	N/A	N/A	N/A
11	4.2	5.7	7.0	8.0	8.7	N/A	N/A	N/A
12	4.4	6.1	7.4	8.5	9.4	10.0	N/A	N/A
13	4.7	6.4	7.9	9.1	10.0	10.7	N/A	N/A
14	4.9	6.7	8.3	9.6	10.6	11.4	12.0	N/A
15	5.1	7.0	8.7	10.1	11.2	12.1	12.7	N/A
16	5.3	7.3	9.1	10.6	11.8	12.7	13.4	14.0
17	5.5	7.6	9.5	11.1	12.4	13.4	14.2	14.8
18	5.7	7.9	9.9	11.6	12.9	14.0	14.9	15.5
19	5.9	8.2	10.3	12.0	13.5	14.7	15.6	16.3
20	6.0	8.4	10.6	12.5	14.0	15.3	16.2	17.0
21	6.2	8.7	11.0	13.0	14.6	15.9	16.9	17.7
22	6.4	9.0	11.3	13.4	15.1	16.5	17.6	18.5
23	6.5	9.2	11.7	13.8	15.6	17.1	18.3	19.2
24	6.7	9.5	12.0	14.3	16.1	17.7	18.9	19.9
25	6.9	9.7	12.4	14.7	16.6	18.3	19.6	20.6
26	7.0	10.0	12.7	15.1	17.1	18.8	20.2	21.3
27	7.2	10.2	13.0	15.5	17.6	19.4	20.8	22.0
28	7.3	10.4	13.3	15.9	18.1	19.9	21.5	22.7
29	7.5	10.6	13.6	16.3	18.6	20.5	22.1	23.4
30	7.6	10.9	13.9	16.7	19.0	21.0	22.7	24.0
31	7.8	11.1	14.2	17.1	19.5	21.6	23.3	24.7
32	7.9	11.3	14.5	17.4	20.0	22.1	23.9	25.3
33	8.1	11.5	14.8	17.8	20.4	22.6	24.5	26.0
34	8.2	11.7	15.1	18.2	20.9	23.2	25.1	26.6
35	8.3	11.9	15.4	18.5	21.3	23.7	25.7	27.3
36	8.5	12.1	15.7	18.9	21.7	24.2	26.2	27.9
37	8.6	12.3	15.9	19.2	22.2	24.7	26.8	28.6
38	8.7	12.5	16.2	19.6	22.6	25.2	27.4	29.2
39	8.9	12.7	16.5	19.9	23.0	25.7	27.9	29.8
40	9.0	12.9	16.7	20.3	23.4	26.2	28.5	30.4
41	9.1	13.1	17.0	20.6	23.8	26.6	29.0	31.0
42	9.2	13.3	17.3	20.9	24.2	27.1	29.6	31.5

REFERENCE: (CMLRD, 1989, p. 43)

SAFETY, HANDLING, AND TRANSPORT

Store PUF materials as specified by manufacturer. Observe all safety precautions outlined by the Polyurethane Division of the Society of Plastics Industries, NFPA, OSHA, EPA, and the manufacturer's Material Safety Data Sheets (MSDS). MSDS and technical data sheets must be on-site and available at all times.

No welding, smoking, or open flames within 25 ft of PUF applications. A minimum 15 lb, class ABC fire extinguisher must be on site during PUF application.

PUF workers must wear organic respirator masks, and safety glasses or goggles. Comply with any more stringent Federal, State, or local safety requirements.

Before and during installation of the bottom form, test air with flame safety lamp or oxygen meter. The oxygen meter shall be a National Mine Service (NMS) OX231 or equivalent, and must have an audible warning. Continuously monitor oxygen levels. Lower the flame safety lamp from the surface to the intended work level of the bottom form. If the flame safety lamp is extinguished upon withdrawal. then the mine may not be entered until the oxygen level increases to acceptable levels. Either lamp or meter shall accompany workers during their time in the mine. Withdraw from the mine if 1) the oxygen meter indicates oxygen content falls below 19 percent, or 2) the quality and/or intensity of the flame safety lamp decreases.

Comply with all applicable State and local regulations for transport of PUF components and spill response.

CONSTRUCTION

Clearing Debris

Clear debris, loose rocks, and other items that interfere with construction, as safety conditions permit.

Form Installation

Place form either 1) a minimum (2 to 4 ft*) distance below the level of competent rock, or 2) at the depth given by Table VII, whichever is greater. First, set cross supports which may be placed at an angle not greater than a maximum (20^{o}*) from horizontal as long as both ends are seated in competent rock. Then set form over cross supports.

Drainpipe and Access-Way (Optional)

With no drainage, surface water may accumulate on top of the PUF plug. If this water is not desirable, install a drainpipe as follows:

* For that part of drainpipe exposed to backfill, cut slits or perforate with holes less than a minimum (0.25 in.*) width or diameter.

* Encase upper end in a steel sleeve (2 in. in diameter greater than pipe and 3 ft long*), and fill annulus with concrete.

* Extend one third of sleeve above final grade line.

* Weld steel strap or equivalent to top of pipe to reduce opening to less than a maximum (2 in.*) size. This prevents large rocks from being dropped and lodged in pipe.

* Cover pipe openings temporarily (visqueen or polyethylene tape*) during PUF application, and remove covering prior to backfilling.

Install access-way and drainpipe, as follows:

* Prior to placing culvert in shaft, weld grated door to top end of culvert. Weld must be continuous around culvert. Under no circumstances shall welding occur over exposed PUF.

* Cut openings in form for culvert and drainpipe.

* Support culvert and drainpipe on surface (tripod set up over shaft) so that form does not take the load. Secure fixtures to form openings.

* Bottom opening of fixtures must not be obstructed by cross supports.

* Extend fixtures a minimum (1 ft*) height above the final graded surface.

PUF Application

The following conditions must be met prior to applying PUF:

* Surfaces free of grease and water.

* No debris.

* Dry weather unless PUF is protected from water by a physical barrier.

* No foreign objects placed in PUF.

Apply PUF in lifts with a maximum (1.5 ft*) rise, as follows:

* Each lift must be tack free stage before applying the next lift.
* Apply PUF such that 1) the entire void is filled, and 2) there are no shadow zones or voids.
* At no time shall sprayed or poured PUF cut into rising foam.
* At no time shall foam temperatures rise to unsafe levels. Thermocouples can be used to monitor temperature of exothermic reactions.
* Stop application if off-ratio PUF or improper heating is observed.
* In backfill section, cover culvert on the outside with a minimum (0.5 in.*) thickness of PUF. PUF may be draped or splashed against culvert to achieve this cover.
* Wait a minimum (1 hr*) time before commencing backfill operations.

Correct off-ratio PUF as follows:

* Remove any off-ratio lift comprising over a specified (2%*) portion of total column.
* Off-ratio PUF less than the preceding maximum may remain if allowed to cool and if the outer perimeter is removed.

PUF Field Quality Control

PUF field quality control includes observation and density testing.

Acceptable PUF is tan-white to buff in color with no vesicles and a smooth to coarse orange peel surface. Stop PUF application if anyone of following conditions is observed:

Condition	Possible Cause
Dark color Smooth and glassy Friable or brittle Improper density	Excess A component
Light color or white Bad cell structure	Excess B component

Mottled appearance
Blowholes or pinholes

Slow rise — Bad material
Poor cell structure
Frequent equipment clogging
Slow curing
Bad physical properties

Test and correct PUF ratio on a plastic sheet away from work area.

Collect density samples in center of shaft opening just above latest PUF lift. A sampling box can be constructed of aluminum and lined with polyethylene. Lower container into position and fill with applicator. Sample density should be within a maximum (8%*) tolerance of required (2 lb per cu ft*) density, and should exceed a minimum (1.85 lb per cu ft*) density.

Adjust ratio for changes in barometric pressure.

Laboratory testing is available for PUF quality and tensile strength. These tests require 1 cu ft samples for quality, and 100 cu in. samples for tensile strength.

Backfilling

After a minimum (1 hr*) curing time, backfilling may commence. Place the first 2 ft lift of backfill by hand, bucket, or chute to lower the velocity of impact against the PUF. In addition, protect drainpipe and culvert from damaged by backfilling.

Install Monument See separate guideline.

REFERENCES: This section paraphrased from CMLRD, 1989, p. 42; CMLRD, 1990, p. 8.

BULKHEAD ADIT CLOSURES

DESCRIPTION

There are two types of bulkheads one built of native rock, and the second built of concrete blocks where the native rock is incompetent or not readily available. See Fig. 9. A bulkhead of native rock and grout is built into the opening of an adit or inclined shaft. Alternatively, the bulkhead can be built with concrete blocks, reinforcing steel, and grout.

May be built with or without a grated access-way.

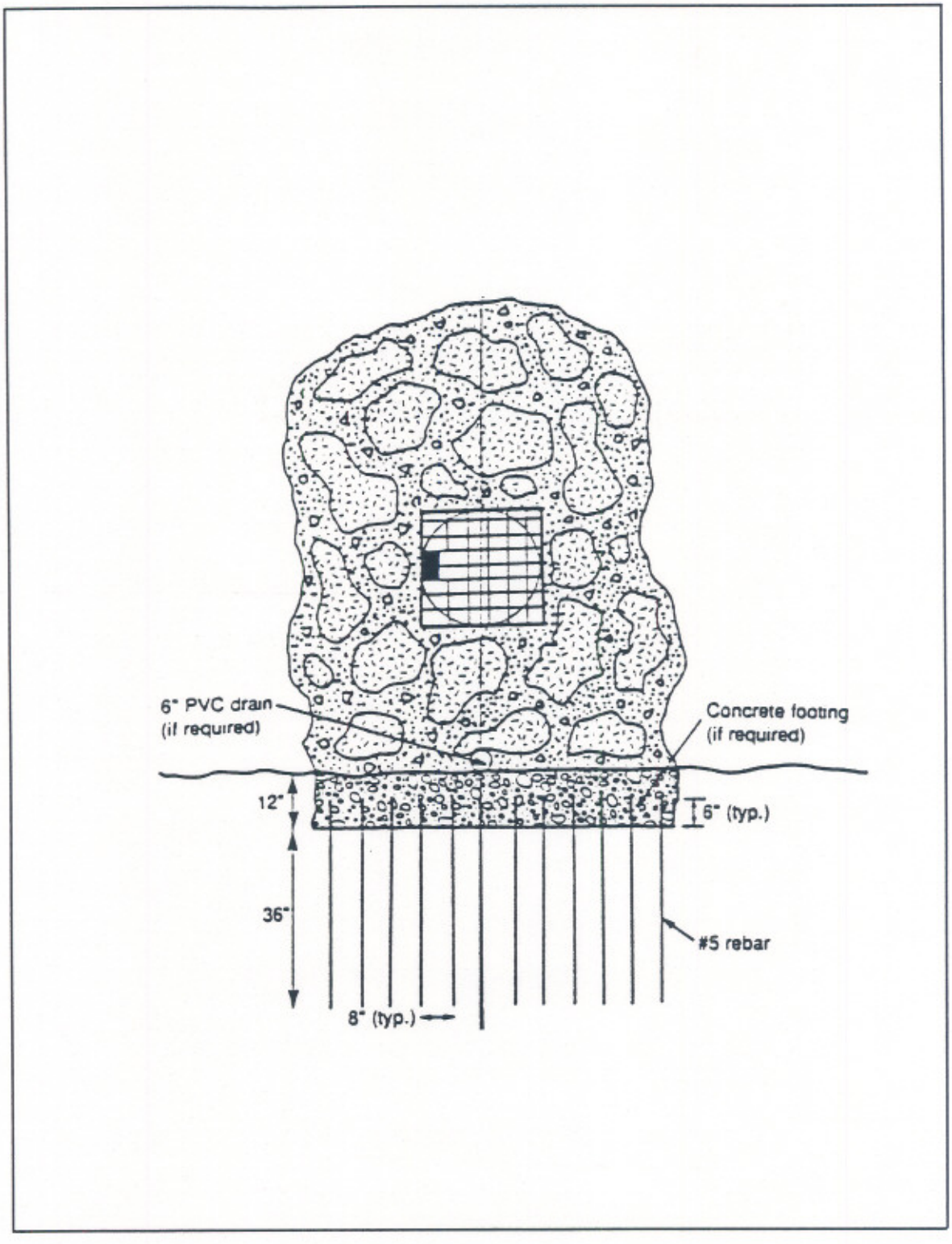

Figure 9. Bulkhead Adit Closures
(CMLRD, 1990)

Advantages: Native rock is indigenous, obtained locally, and visually less obtrusive. Applicable where the site is difficult to backfill or blast, very remote or access very difficult. Minimal construction impacts.

Disadvantages: Labor intensive. May not be as visually unobtrusive as backfilled or blasted closures.

Cost: $1 200 to $7,000 per project.

MATERIALS

Rock: Durable and produces a ringing sound when struck with a hammer (indicating lack of fractures).

Concrete Blocks: Refer to NPS standards.

Reinforcing steel: Specified by qualified structural engineer.

Grout: Refer to NPS standards.

Drainpipe: Noncorrosive, sized for potential flow.

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.*

Grated access door (optional): See separate guideline.

CONSTRUCTION

For native rock, minimum wall thickness is 30 in. for 8 ft maximum adit dimension, 36 in. for 8 to 10 ft, and 42 in. for 10 to 12 ft*.

For concrete blocks, a single block wall is generally adequate for openings up to 8 by 8 ft. Use a double block wall for openings up to 15 by 15 ft.

Choose another closure method for larger openings.

Foundation

Place bulkhead in bedrock. Clear bulkhead site of all unconsolidated material prior to construction.

Install a footer, If bedrock is in excess of a maximum (36 in.*) depth below the original excavated floor, install a footer as follows:

* Place bottom of footing a minimum (3 ft*) depth below grade.

* Compact foundation to a minimum density.

* Drive No. 5 rebar on minimum (8 in*) centers into foundation floor to minimum (36 in*) depth or refusal.

* Pour concrete footing (12 in. deep, 30 in. wide*).

Installation

Lay and mortar rock/blocks on foundation, and build bulkhead as close as possible to adit sides. In block walls, use partial blocks to minimize gaps.

* Grout all spaces between bulkhead and adit.

* Grout spaces between rocks/blocks and between courses.

* Cap top rocks/blocks.

* There must be no spaces between bulkhead and sides of adit.

For concrete blocks, incorporate the following reinforcement:

* On minimum (32 in.*) centers, grout inside space of concrete block and insert (No. 5*) reinforcing steel.

* On each side of access-way, grout inside space of concrete block and insert two (No. 5*) reinforcing steel.

* On each block course, insert two (15/16 in.*) wires on 16 in. spacing (or prefabricated equivalent such as Durawall). Only required on outer tier of double-block bulkheads.

* On double-block bulkheads, insert (No. 9*) wire, rectangular ties on 24 in. horizontal and vertical spacing.

For improved visual effect, mortar native rock of minimum (12 in.*) diameter to the exterior wall for the entire width and height of concrete block bulkhead.

Drainpipe and Access-Way

Where water discharges from the adit, install a drainpipe at bottom of bulkhead. Extend drainpipe a minimum (5 ft) distance beyond each side of bulkhead. Attach a minimum (12 in.*) perforated riser to the inside end. To reduce blockage, cover both ends with (2 in. mesh, 7 ga.*) rubber coated wire.

If access is required:

* For rock bulkhead, lay a horizontal culvert with grated door in the bulkhead as the wall is built up.

  For concrete block bulkhead, frame a 4 by 4 ft opening in the center of the bulkhead with welded C 10 X 20's. Weld grate door to frame.

Install Monument See separate guideline.

REFERENCE: This section paraphrased from CMLRD, 1990, p. 12 & 14.

GRATE ACCESS DOORS AND COVERS

DESCRIPTION

Locking steel doors and grate covers for corrugated steel pipes (culverts), grate closures, and bulkheads. See Fig. 10.

MATERIALS

Grating, grate frame, door frame, and lock steel: Carbon steel, specified by qualified structural engineer.

Paint: Zinc-rich.

FABRICATION

Fabricate steel door or steel grate generally in conformance with the following instructions:

* Fabricate solid grate with 2 1/2 in. by 3/8 in. bearing bars on 1 3/16 in. centers, and cross bars on 4 in. centers. Equivalent commercial grating is available.

* Fabricate frame from L steel 3 by 3 by 3/8 in. Size frame to fit opening.

* Weld grate to frame at least very other bearing bar.

  Fabricate a lock box from 1/4 in. thick steel plates. Weld all edges, and smooth burrs and rough edges. Size to accommodate a specified (No. 3 Master Lock with 1 1/2 in. shackle*) lock. Free play between hasp and door must not exceed 1/4 in. when locked.

  Fabricate extra heavy duty (4 in.*) long door hinges with non-removable pins. Weld or bolt to hinge plate and grate frame. Weld or grind bolts to make them non-removable.

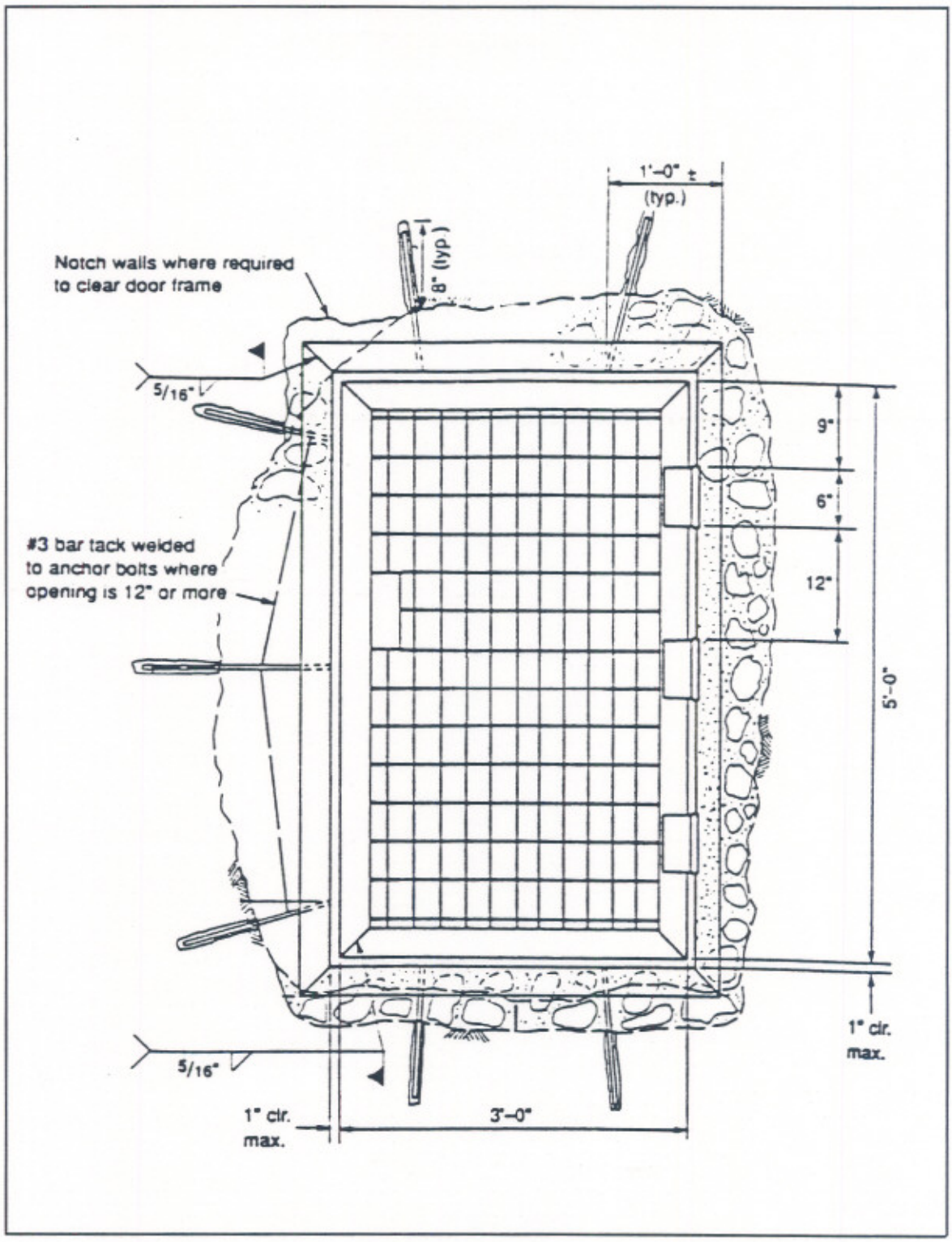

Figure 10. Grate Doors and Covers
(CMLRD, 1990)

In the field, weld door cover to opening frame continuously around fixture. Paint entire fixture with a zinc-rich protective coating.

REFERENCE: This section paraphrased from CMLRD, 1989, p. 10.

MONUMENTS

DESCRIPTION

On each closure, install an identification monument that is visible to the eye or a metal detector in the case of backfills.

MATERIALS

Brass cap

Marker Pipe: 3 in. diam, noncorrosive (PVC, ABS, or HDPE).

CONSTRUCTION

Install brass cap on either grate, culvert, or exposed top end of buried marker pipe.

For grates or culverts, permanently braze brass cap to fixture. Care must be taken not to overheat the cap, which may result in breakage.

For other closures, bury pipe with the embedded end set in concrete closure cap or backfill. In backfills, encase buried end in a concrete footing (2 ft long, 1 ft dia.*).

* Extend exposed top end (1 ft*) beyond final graded surface.

* Fill pipe with high slump concrete.

* Grout brass cap into the pipe end using a nonshrink grout such as Pour-Rock, Kwik-Crete, or Epoxy Bond.

On occasion, it will not be feasible to set monument within closure, for example a blast closure. In this case, drill a short (2 in. diam. by 8 in. long*) hole in competent rock as close to closure as possible. Install brass cap with anchor and nonshrink grout.

REFERENCE: This section paraphrased from CMLRD, 1989.